DER Technologies and Features

FEDERAL ENERGY MANAGEMENT PROGRAM

DER Hands-on Training

March 12, 2003

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A Matter of Terminology

- DG, DER
  - Why are they called “Distributed”?
  - Difference between DG and DER
- Microgrids and Power Parks
  - Are they different?
- CHP, BCHP, CCHP, Cogeneration

Distributed Generation Technologies

- IC Engines
- Combustion Turbines

- Microturbines
- Fuel cells
- Energy Storage
- Photovoltaics
- Wind

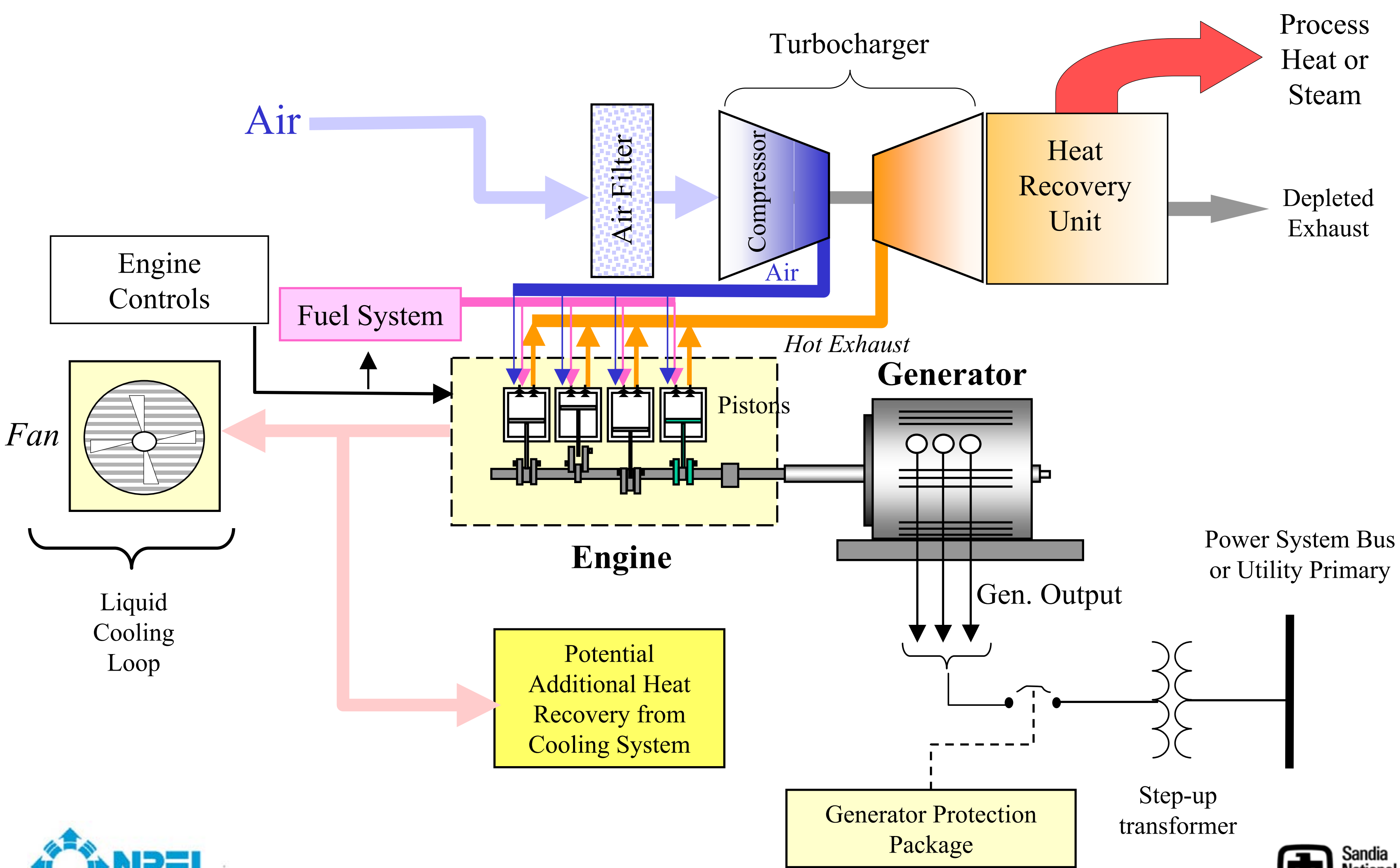
- Others

DG Technologies

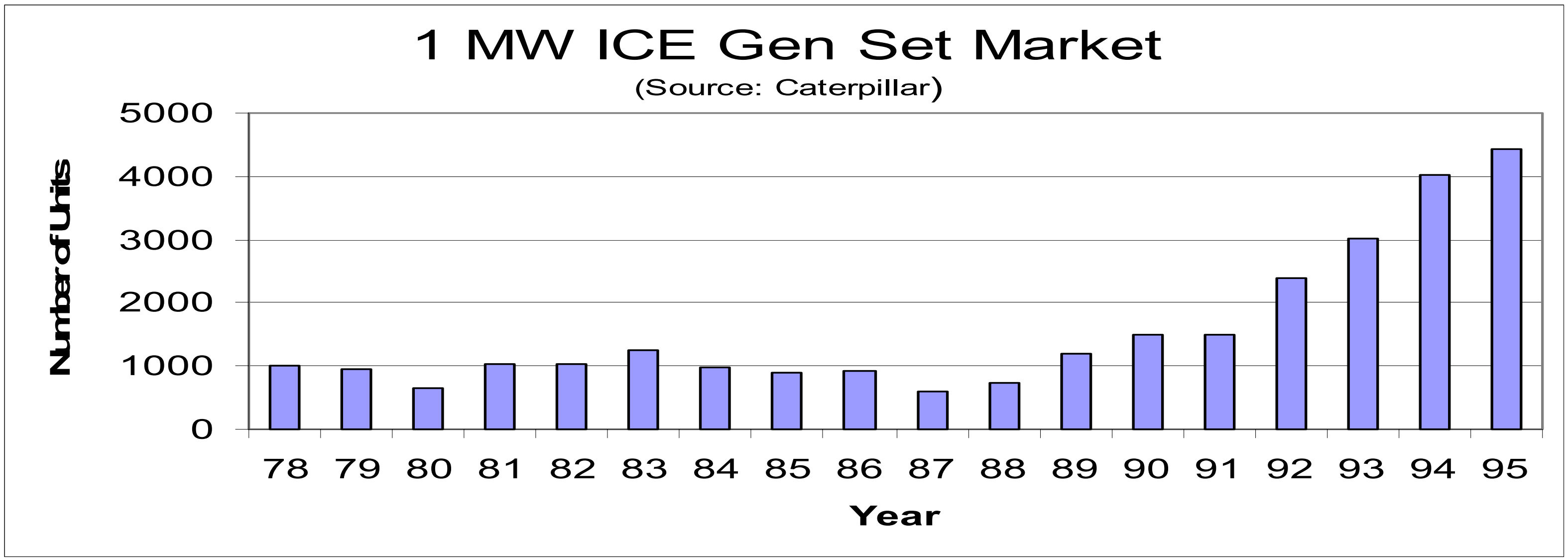
- Schematics and functional detail
- Typical configuration
- Commercial readiness and some manufacturers
  - Models and sizes

- Cost and Performance
  - FEMP Table

Schematic of an Internal Combustion Engine/Generator



ICE generator market has grown dramatically in recent years



Market growth in the 1990's shows a trend among industrial/commercial users for standby power & DG applications!

Modular Container Integrated ICE DG

Modular container houses IC engine- generator, switchgear, generator controls, cooling equipment, and fuel controls in a single package

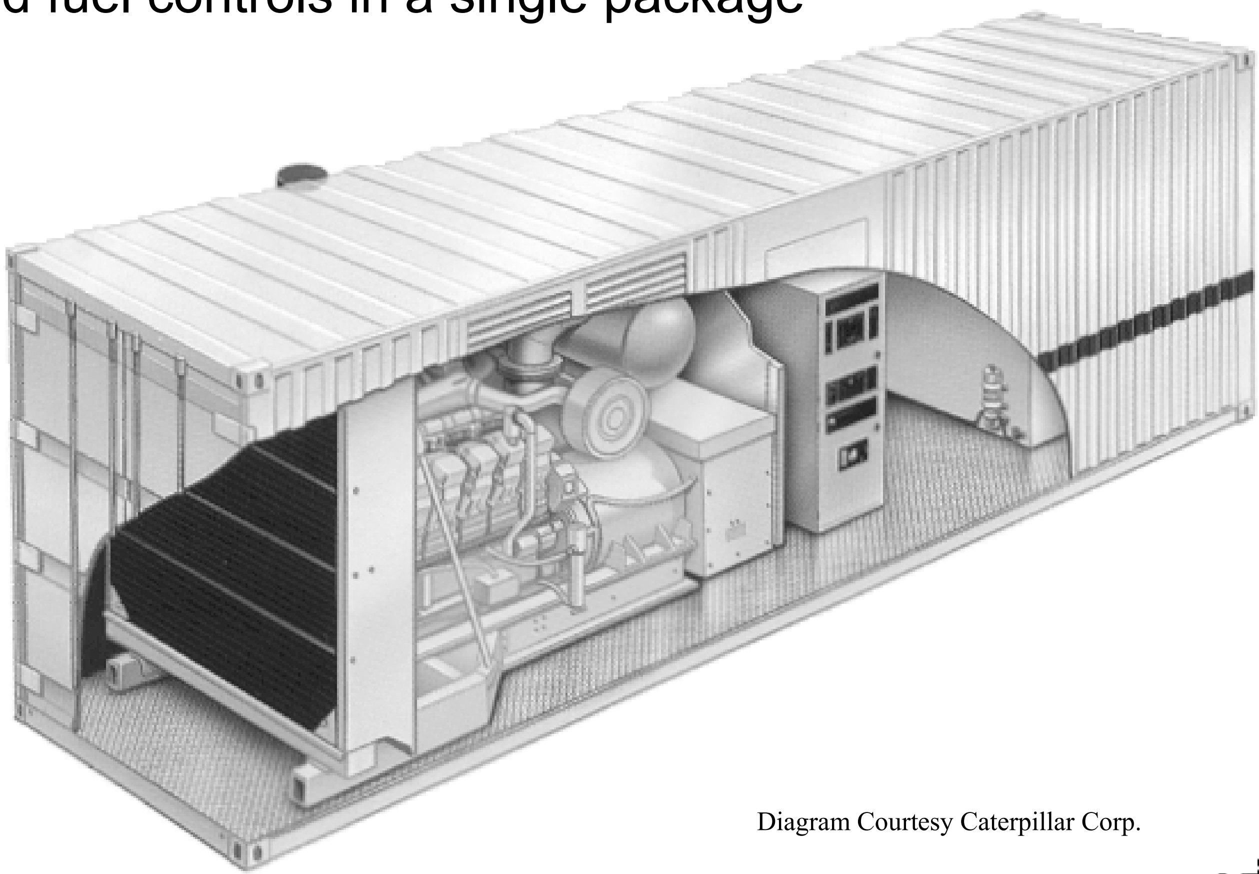
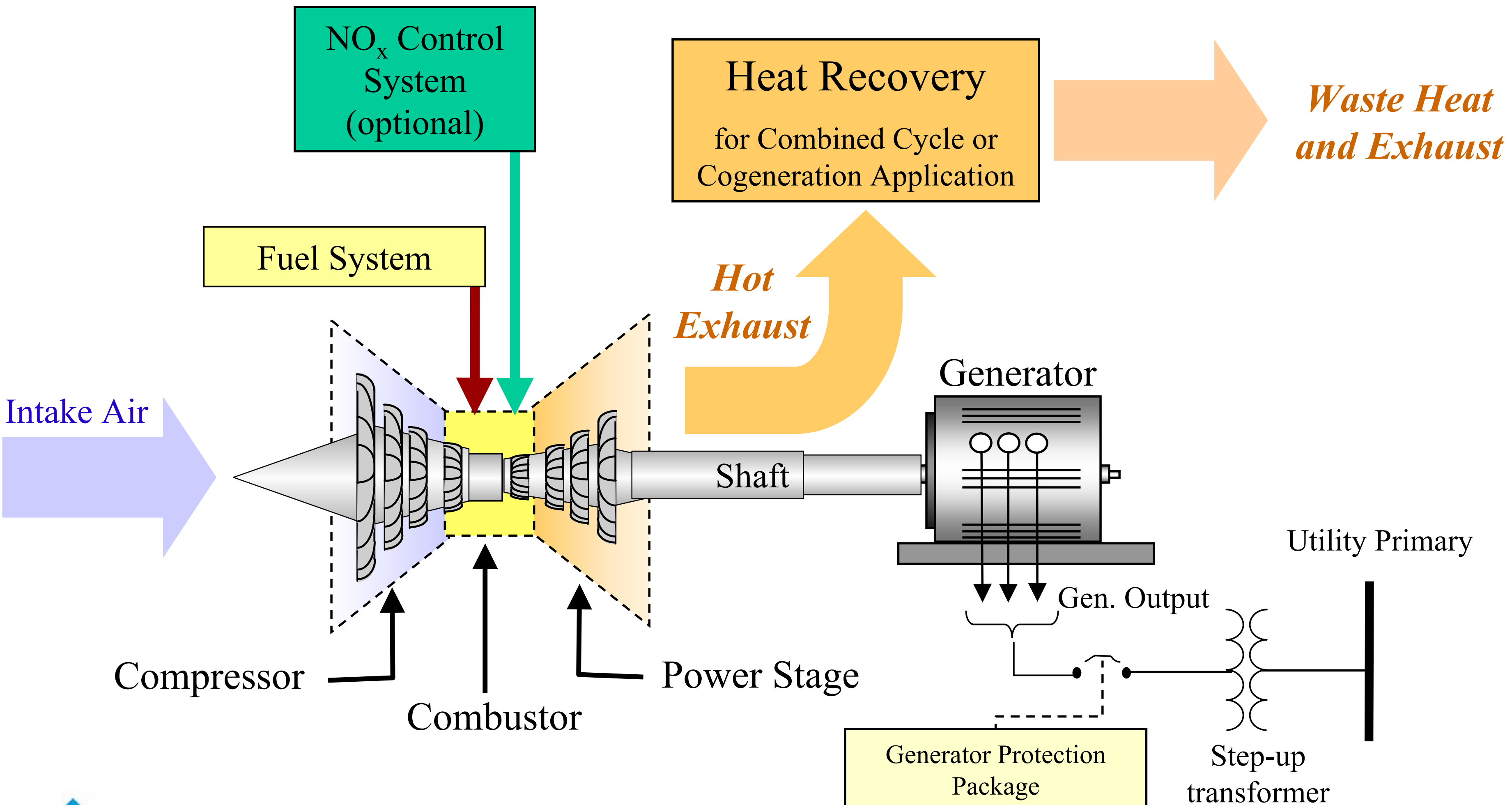


Diagram Courtesy Caterpillar Corp.

Multiple Caterpillar ICE Units Applied for T&D support

Photo Courtesy Caterpillar Corp.

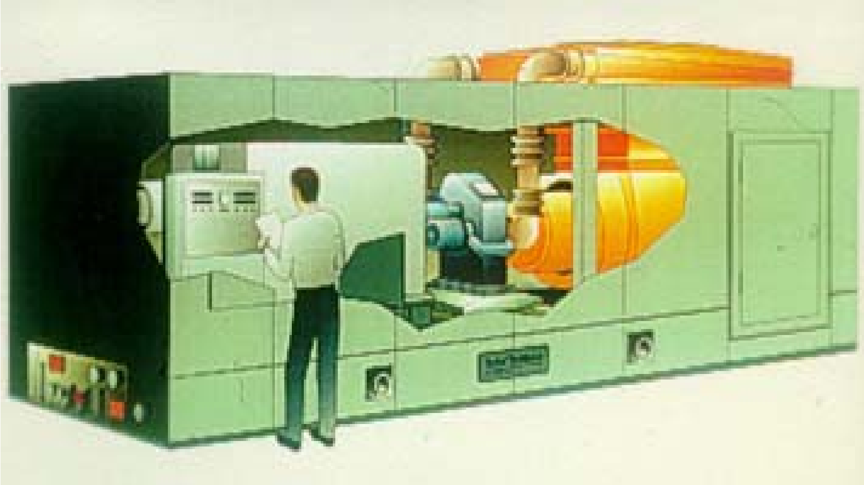
Schematic of a Combustion Turbine



Combustion turbines will dominate early markets for DR

50 MW Aero-derivative - GE

4 MW - Solar Turbine



Modular Combustion Turbine Lowered by Crane for Installation

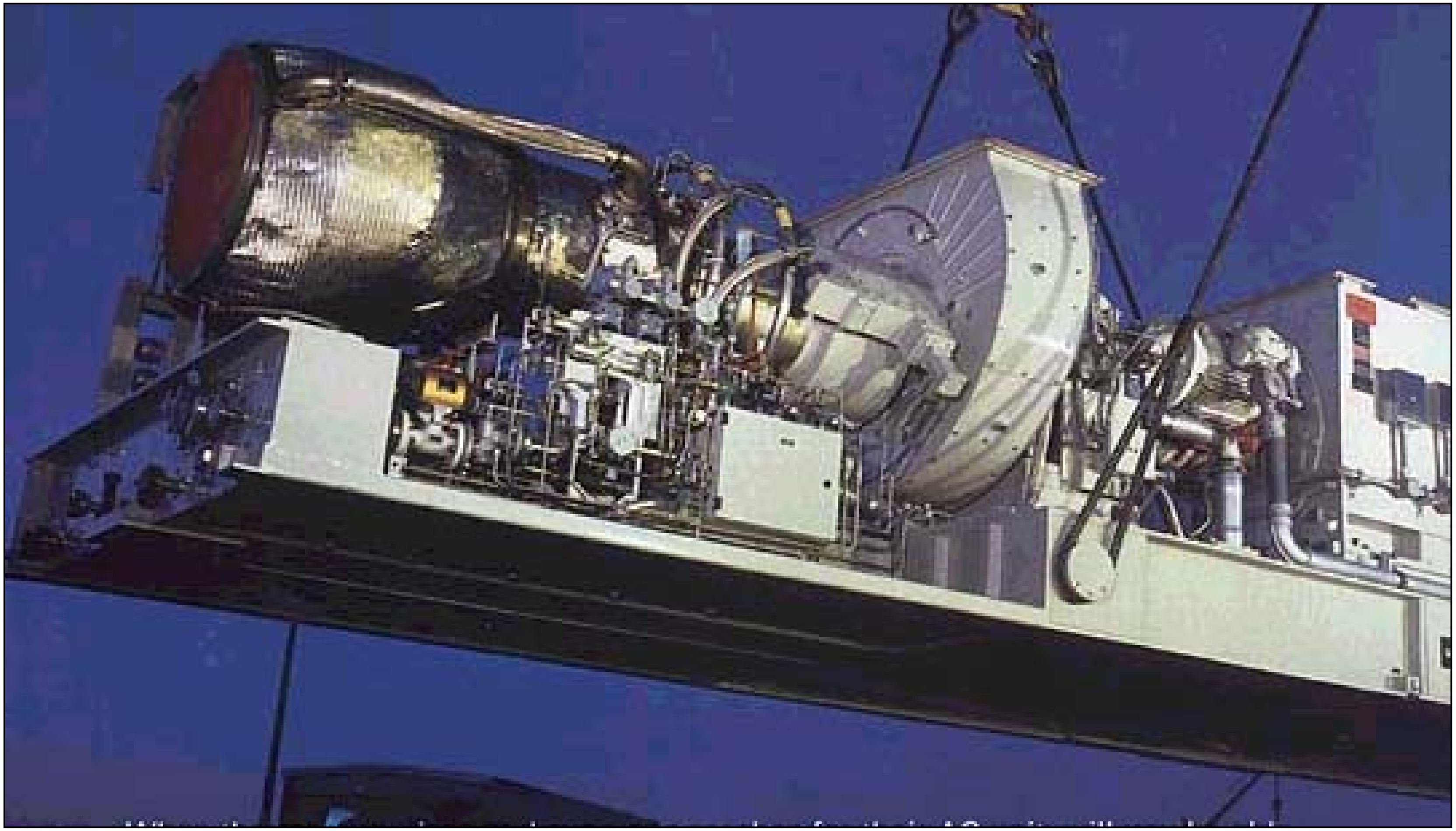
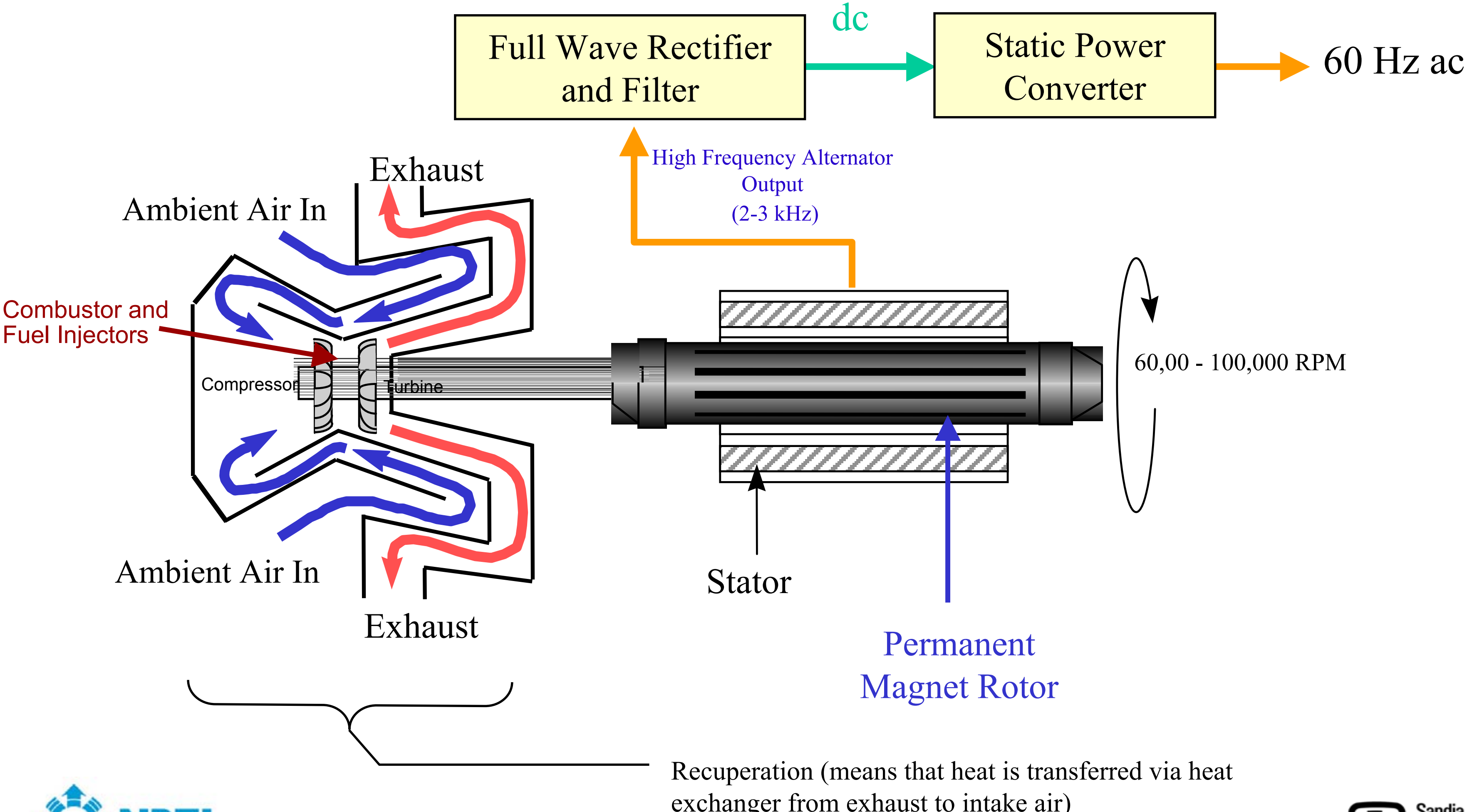


Photo courtesy Solar Turbines

Typical Micro Turbine Components



Microturbine Product Details

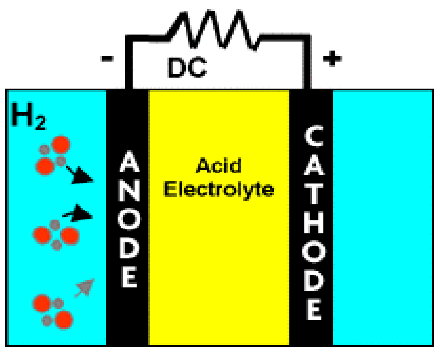
- Manufacturers and sizes
  - Ingersoll-Rand PowerWorks: 70 kW
    - Induction and synchronous generators available
    - Natural gas, landfill gas
    - Indoor applications
    - CHP machine
  - Capstone: 2 sizes: 30 and 60 kW
    - Grid-connected or stand-alone
    - Natural gas, landfill gas
    - Power electronics interface
    - Add-on CHP module available as an option

Representative Models

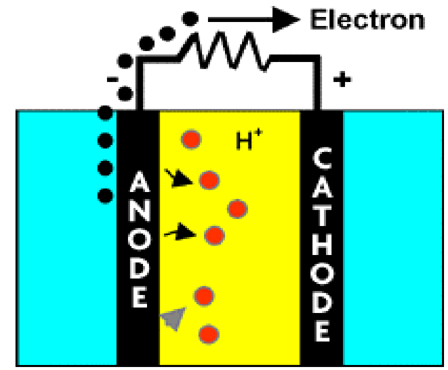
Ingersoll-Rand PowerWorks
70 kW

Capstone Microturbines
30 kW models shown

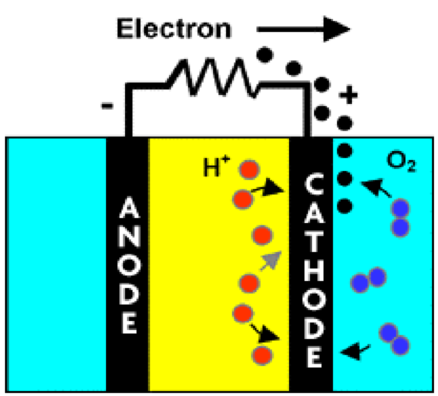
Principle of Fuel Cell Operation



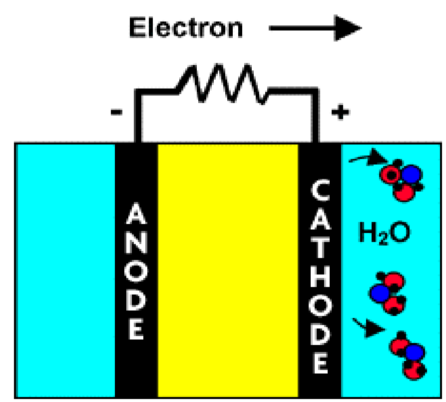
A. Hydrogen gas flows over the anode



B. Electrons are stripped from the hydrogen and flow through the anode to the external circuit



C. Hydrogen ions move through electrolyte to cathode.
Electrons move into cathode from load
Oxygen is introduced to the cathode.



D. Hydrogen ions, electrons, and oxygen combine to form water (steam)

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Diagrams Courtesy U.S. Department of Defense

Four Major Types of Fuel Cells

Polymer Electrolyte Membrane (PEM)

- T < 100°C
- Billions $ investment for transportation applications
- need fuel reformers
- Platium Catalyst

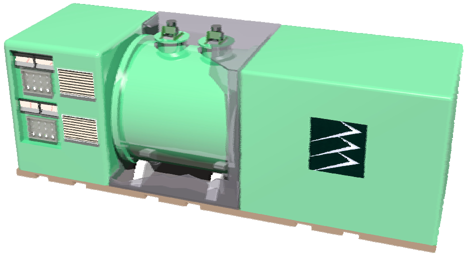
PlugPower 7 kW Unit

Phosphoric Acid Fuel Cells

- T = 200°C
- Commercially available
- Low efficiency
- High Cost

ONSI 200kW PAFC unit

Molten Carbonate Fuel Cells



- T = 650°C
- Electrolyte Mgt.
- Low Power Density
- High Cost

Fuel Cell Energy 250 kW unit

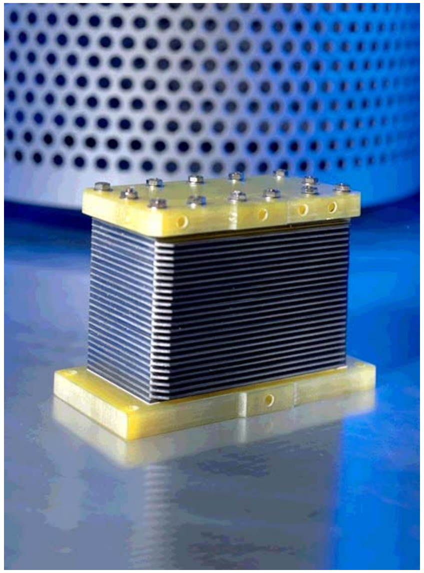
Solid Oxide Fuel Cells (SOFC)

- T =1000°C
- scale-up
- seals
- durability
- high temperature

Siemens Westinghouse 100 kW unit

Examples of PEM Fuel Cells

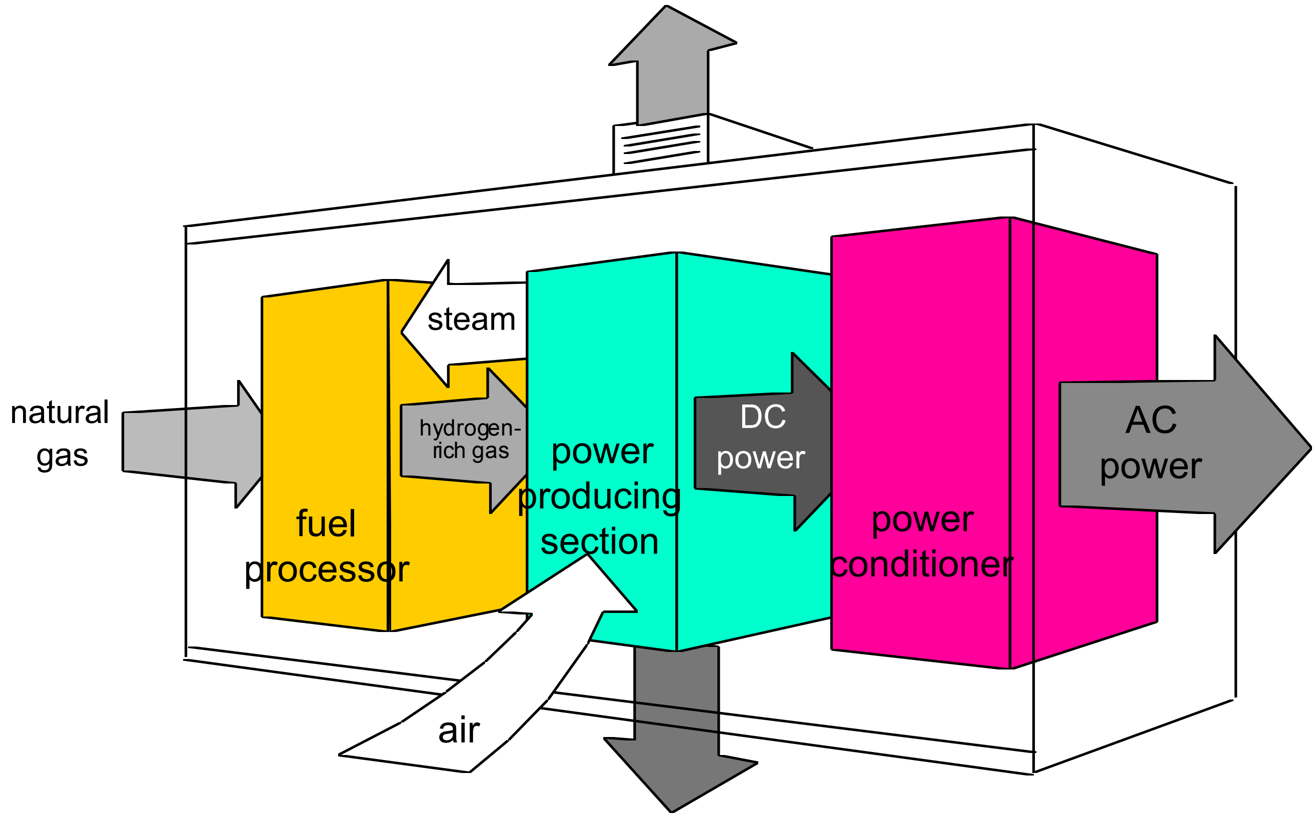
A PEM power system



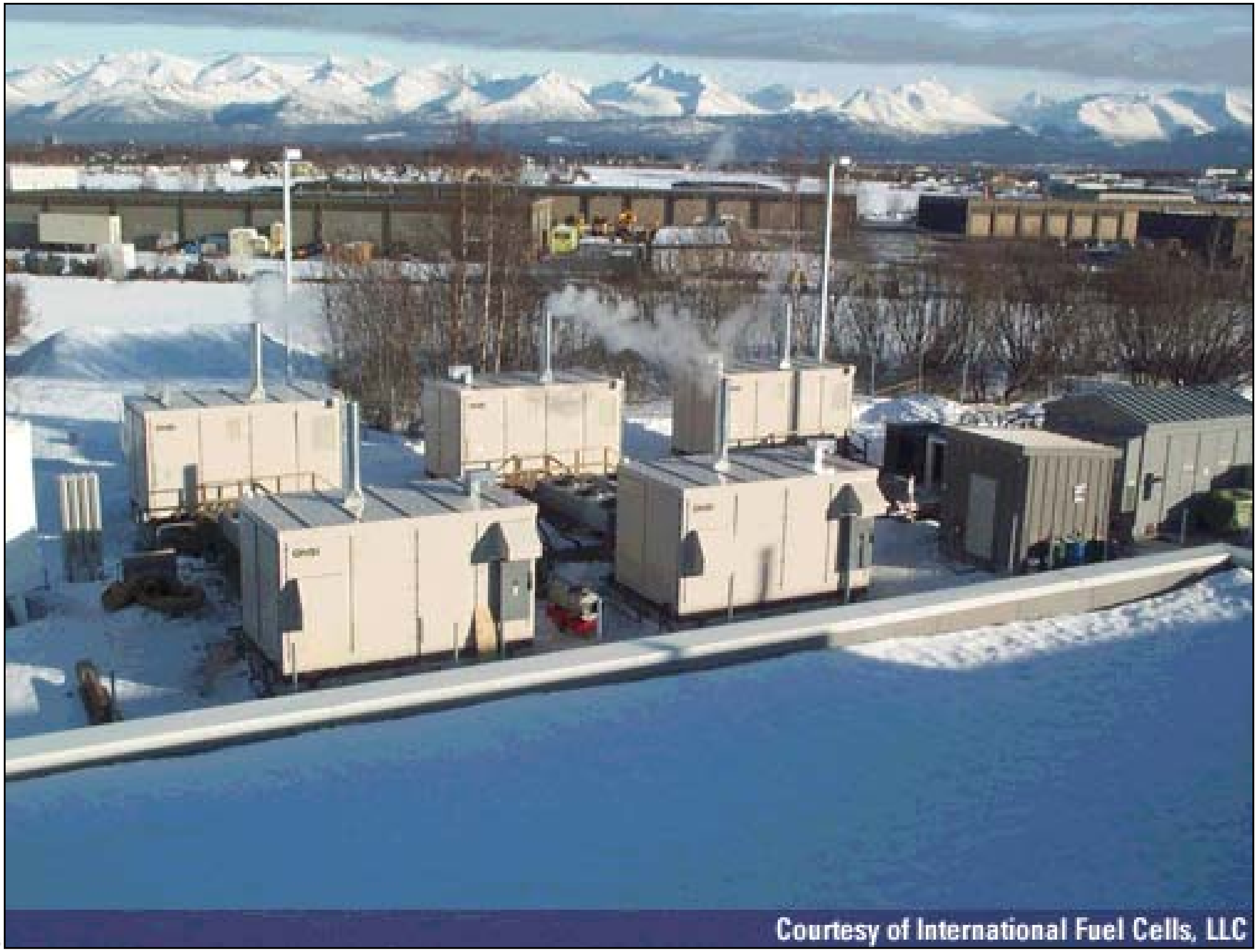
A small PEM Fuel cell stack

Photo's Courtesy of H-Power Corp.

Schematic of a Fuel Cell Power System



PAFC Fuel Cells at Anchorage Post Office



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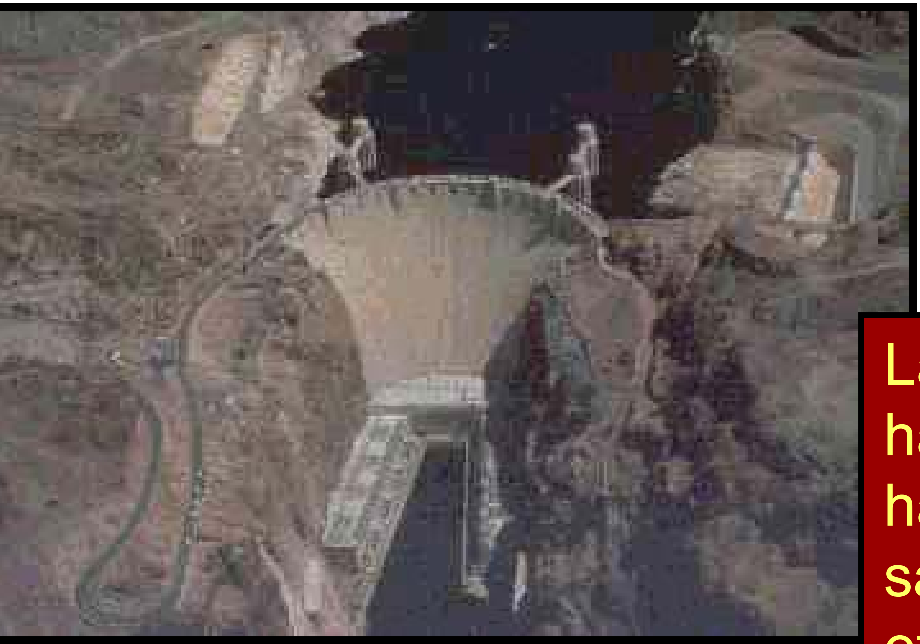
Anchorage Project Writeup

Adobe Acrobat
Document

Myth that Solar Energy Uses too Much Space



Lake Mead formed by Hoover Dam has an area of 640 km^2. The dam has a capacity of 2,080 MW. If the same area was covered with 15% efficient solar modules, the peak solar output at noon could be at least 60,000 MW!

This includes a large margin for DC-AC inverter loss and the spacing between PV array rows

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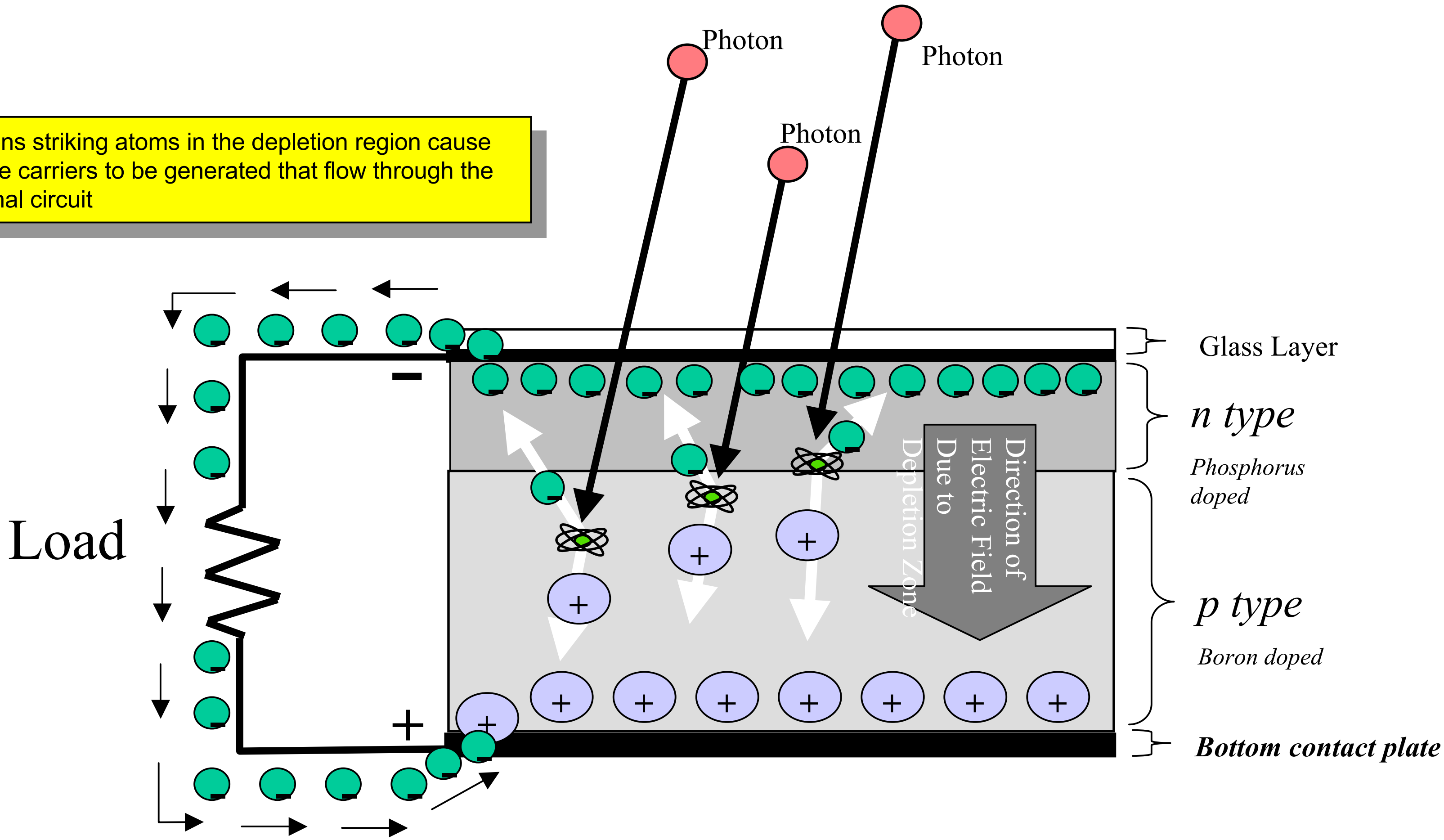
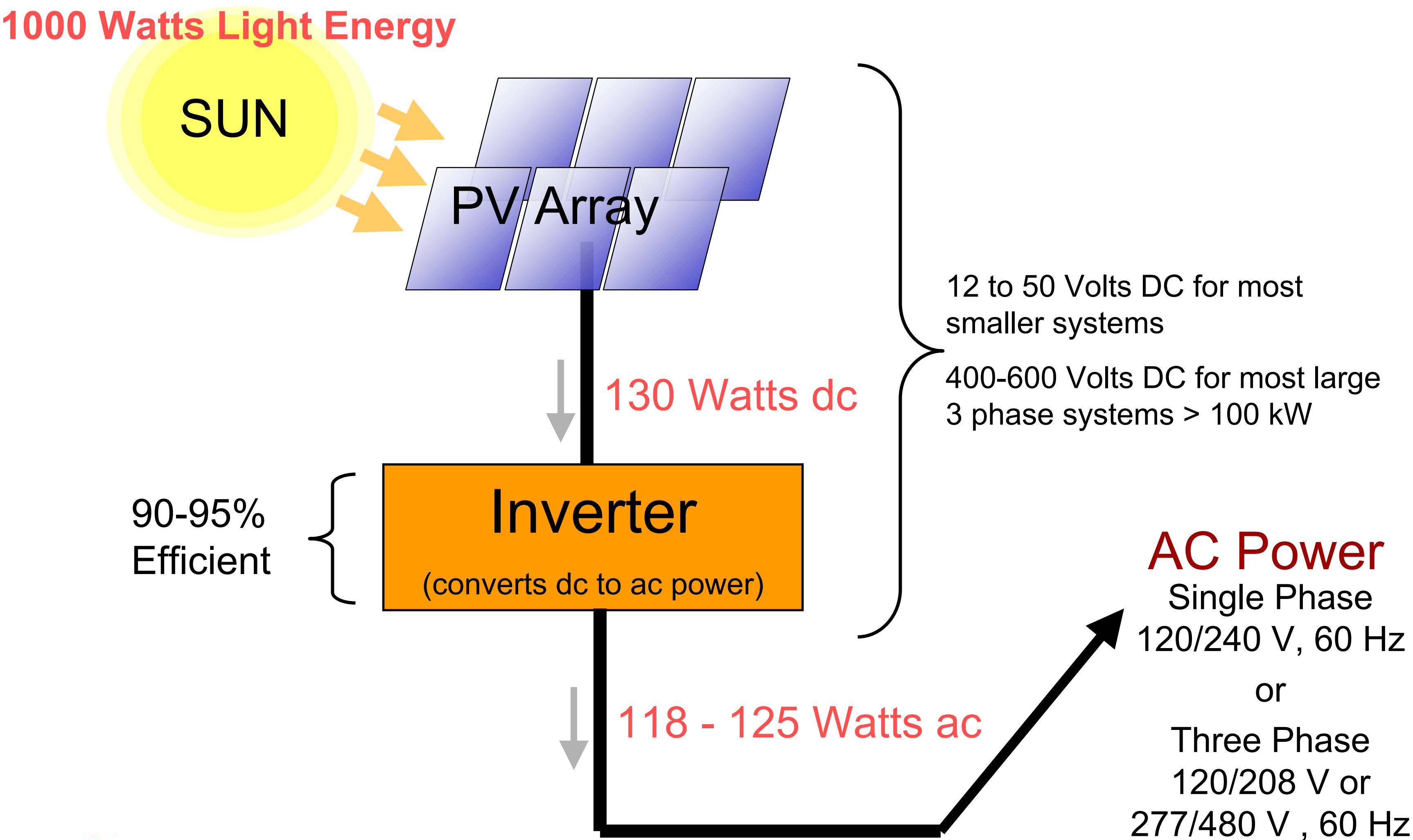
Photovoltaic Effect

Photons striking atoms in the depletion region cause charge carriers to be generated that flow through the external circuit



PV Power Efficiency



Photovoltaic Installations

Building Integrated PV

PV Concentrator Systems

Photo's Courtesy NREL

Building Integrated PV

Photo Credit Warren Gretz

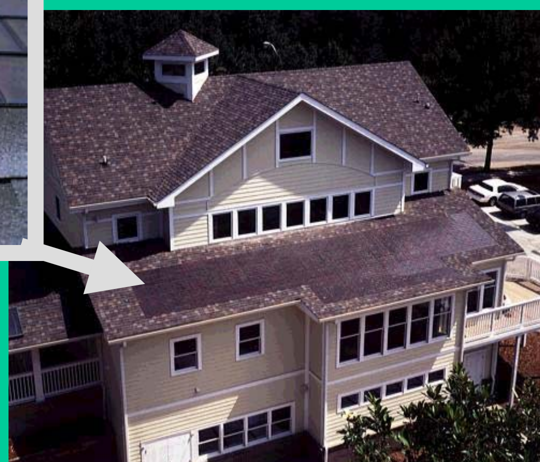


Photo Credit John Haigwood

Photo Credit PowerLight Corporation

Photos Courtesy NREL

Wind Power

- Wind Power is a major success story
- About 5,000 MW will be installed this year (world wide)
- About 17,000 MW total accumulated world capacity has been installed
- Costs are now under 4 cents/kWh

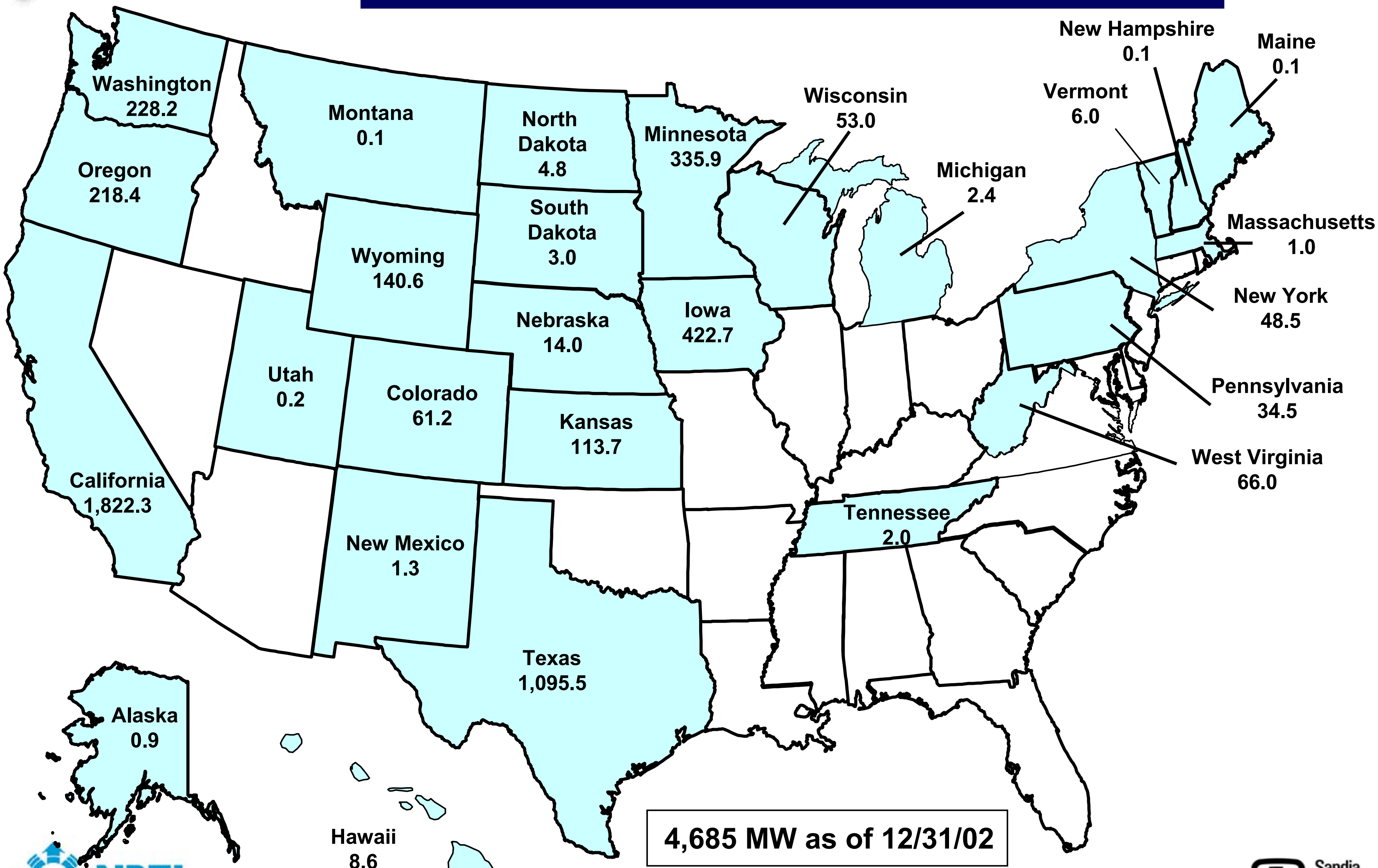
Small and large scale wind turbines

Photo Credit: Brian Smith & NREL

Photo Credit: Bergey & NREL

Photos Courtesy NREL

US Capacities by State

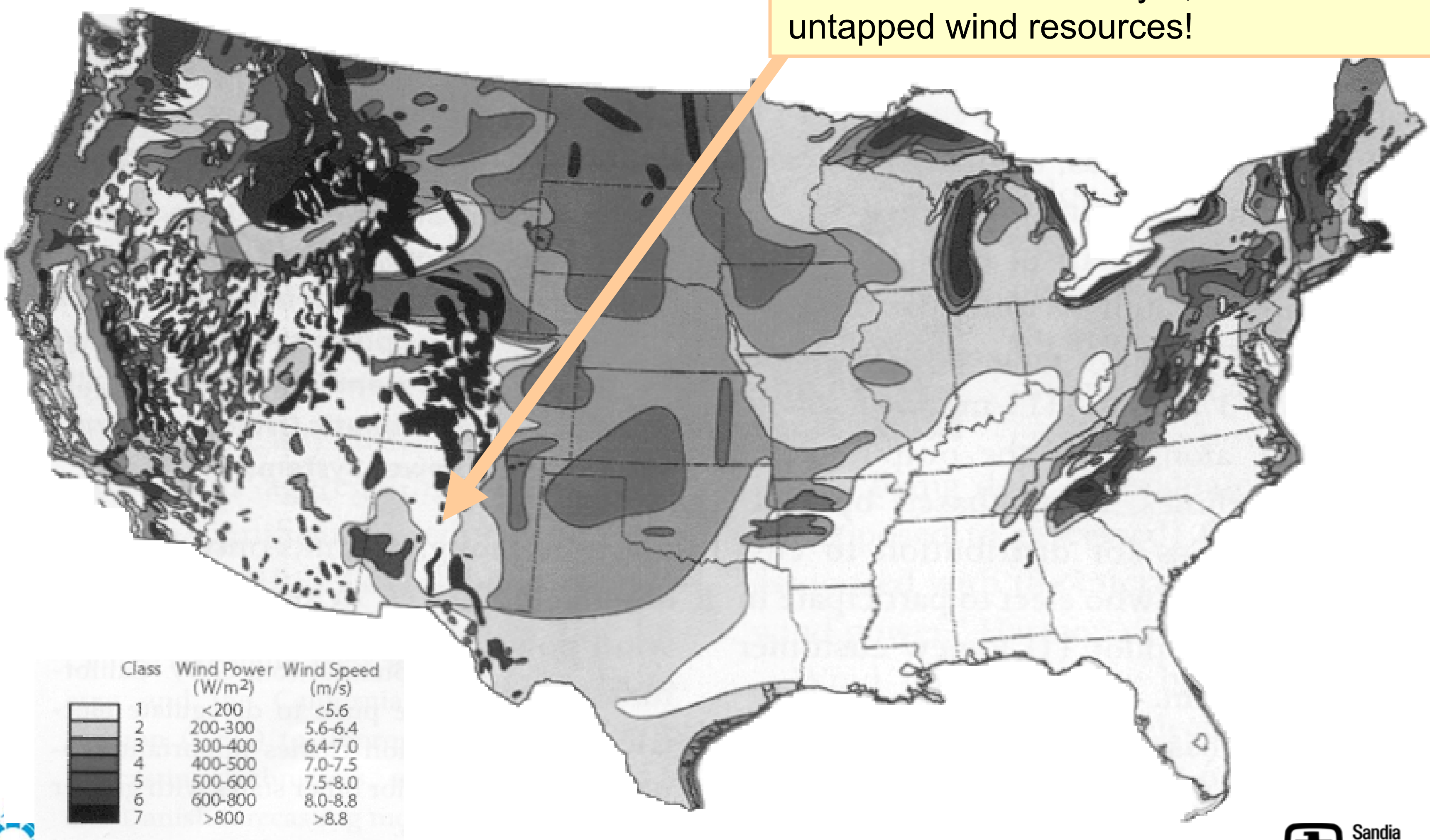


4,685 MW as of 12/31/02

Map courtesy of NREL

Wind Resource Map

New Mexico has nearly 5,000 MW of untapped wind resources!



Courtesy: NREL

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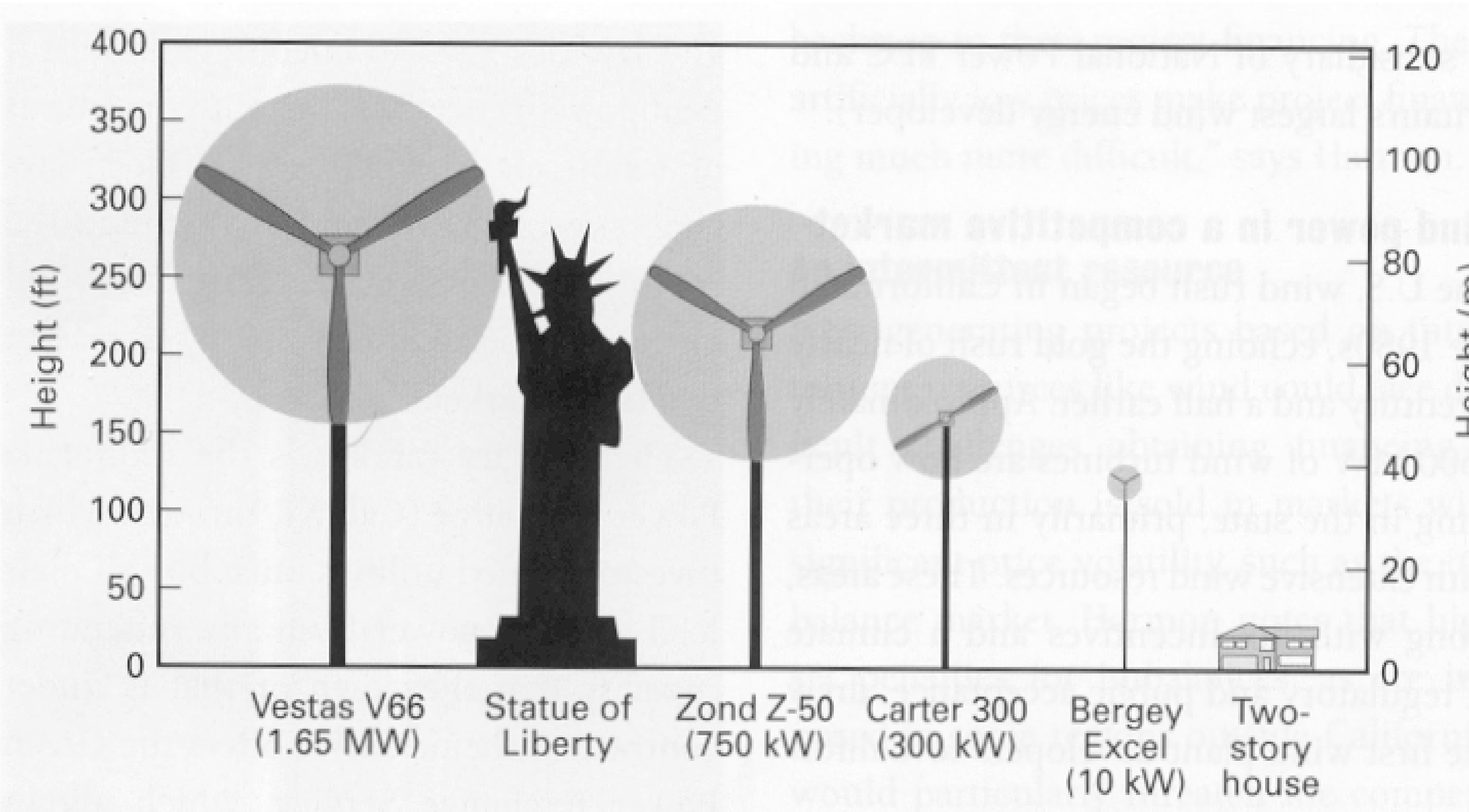
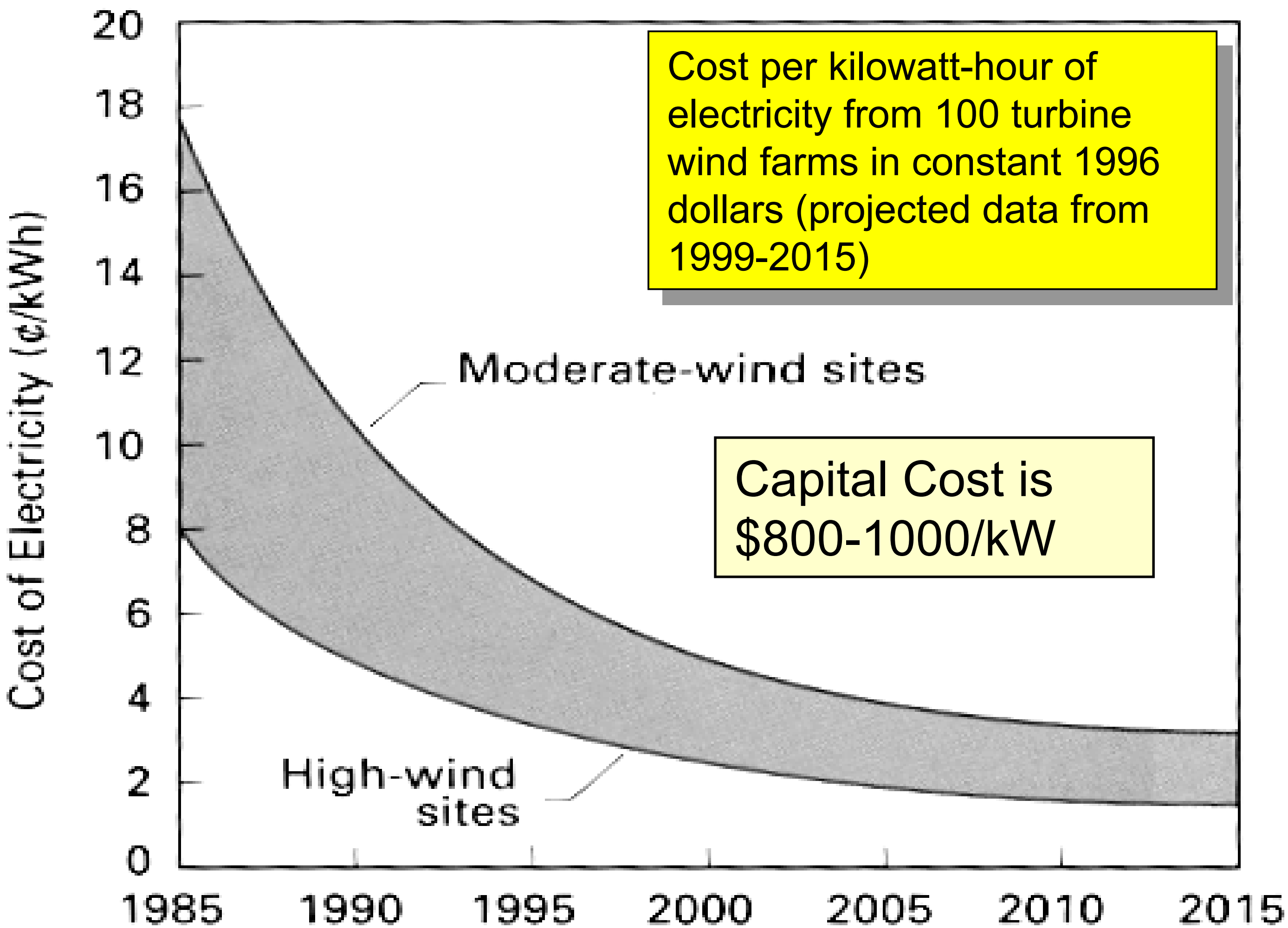
Relative Size of Wind Turbines



Green Mountain Power Wind Facility
Searsburg, Vermont - 6MW

Photo Courtesy Enron Wind Corp.

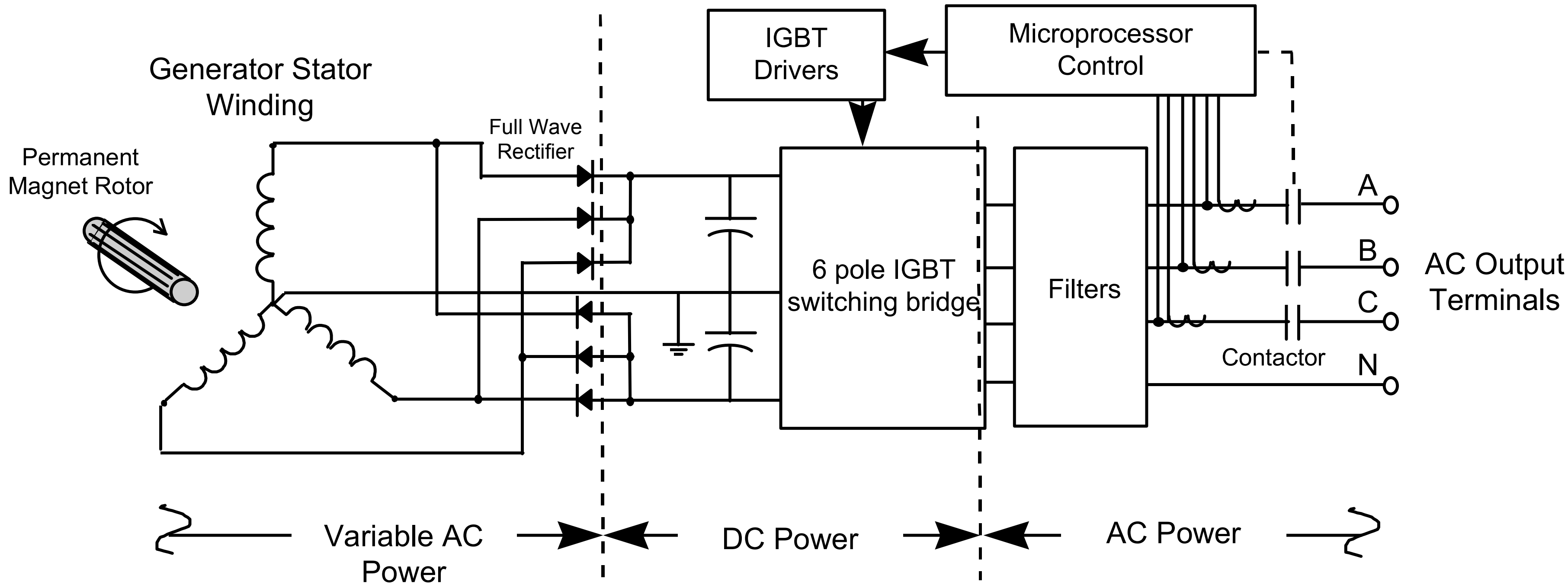
Wind Power Cost Projections



Cost per kilowatt-hour of electricity from 100 turbine wind farms in constant 1996 dollars (projected data from 1999-2015)

Capital Cost is $800-1000/kW

Large Wind Turbine Configuration



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Where is Wind Headed?

- Continued price reductions are expected for large installations - about 2-3 cents per kWh can be achieved
- Wind will be a significant contributor to new utility generation for T&D system support during the next 10 years
- Sense larger (>10 MW) wind farms yield the best economics these will be the bulk of new capacity added
- Small scale wind (<50 kW) will also make inroads due to improving economics but mainly in rural areas due to zoning issues in suburban areas
- New energy storage technologies, may dramatically increase the value of both wind power making it truly dispatchable!

Reasons for Decline in Wind Energy Costs

- Variable speed designs and better blade materials have increased the efficiency of systems
- Increased scale of production (economies of mass production)
- Power conditioning units have replaced less effective direct coupled induction units
- Individual turbines have grown in size yielding economies of scale. The latest generation being about 1.5 to 2 MW per turbine.

FEMP

Energy Storage

- Batteries
- Flywheel
- Supercapacitors
- SMES

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FEMP

Cost and Performance Summary

Table 2. Summary of Cost and Performance Parameters for Distributed Generation Technologies

Technology	Size Range (kW)	Installed Cost ($/kW)	Heat Rate (Btu/kWh)	Approx. Efficiency (%)	Variable O&M ($/kWh)	Emissions (1) (lb/kWh)	
						NO_x	CO_2
Diesel Engine	1–10,000	750–850	7,800	45	0.025	0.017	1.7
Natural Gas Engine	1–5,000	825	9,700	35	0.025	0.0059	0.97
Natural Gas Engine w/CHP	1–5,000	1,100	9,700	35	0.027	0.0059	0.97
Dual-Fuel Engine	1–10,000	875	9,200	37	0.023	0.01	1.2
Microturbine	30–250	650–1,500	12,200	28	0.014	0.00049	1.19
Microturbine w/CHP	30–250	1,100	12,200	28	0.014	0.00049	1.19
Combustion Turbine	300–10,000	900–1,400	11,000	31	0.024	0.0012	1.15
Combustion Turbine w/CHP	300–10,000	950–1,600	11,000	31	0.024	0.0012	1.15
Fuel Cell	100–250	5,500+	6,850	50	0.010–0.050	0.000015	0.85
Photovoltaics	0.01–8	8,000–13,000	--	N/A	0.002	0.0	0.0
Wind Turbine	0.2–5,000	1,000–3,000	--	N/A	0.010	0.0	0.0
Battery	1–1,000	1,100–1,300	--	70	0.010	(2)	(2)
Flywheel	2–1,600	400	--	70	0.004	(2)	(2)
SMES	750–5,000	600	--	70	0.020	(2)	(2)
Hybrid Systems	1–10,000	(4)	(3)	(3)	(3)	(2)	(2)

(1) Nationwide utility averages for emissions from generating plants are 0.0035 lb/kWh of NO_x and 1.32 lb/kWh of CO_2.
(2) Storage devices have virtually no emissions at the point of use. However, the emissions associated with the production of the stored energy will be those from the generation source.
(3) Same as generation technology selected.
(4) Add cost of component technologies.

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